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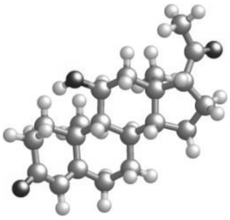


Atomic Structure and Chemical Bonding – Concepts: Change, Models & Systems – Answers

All matter is essentially composed of three different particles – electrons, neutrons and protons – which combine together in different numbers to create the 118 chemical elements. Most of these elements can, in turn, combine together in different quantities to create the wide variety of diverse substances that we encounter in our everyday lives. Not all of these elements are useful to chemists. For example, the elements in Group 18 (the noble gases) are almost completely unreactive while many of the very heavy elements are unstable and consequently radioactive, their nuclei flying apart in a matter of seconds.

To illustrate this further, consider a cell in your body. It contains different organelles such as the mitochondria, nucleus and ribosomes. These structures are, in turn, composed of molecules of different compounds such as amino acids, carbohydrates, DNA and lipids. These molecules are composed of atoms of the different elements, and the atoms are composed of electrons, neutrons and protons. Although 118 chemical elements are known to exist, approximately 99% of the human body is composed of only six elements; oxygen, carbon, hydrogen, nitrogen, calcium and phosphorus. Another 0.85% of the human body is composed of another five elements; potassium, sulfur, sodium, chlorine and magnesium. The rest of the human body is composed of slightly more than one dozen trace elements, including iron and zinc. The compounds that exist in the human body can be classified as either ionic or covalent, depending upon how the atoms are bonded together.

• More to explore. Use a QR Code reader on your iPad to investigate more information about the chemical elements, and find out what your body is composed of.

• BBC News Article: How do we know that things are really made of atoms?	• BBC News Article: How many more chemical elements are there for us to find?	• Interactive Infographic: How much of your body is your own?

• Exactly why electrons, neutrons and protons combine together to form atoms is physics, but why atoms of the different elements combine together to form compounds is the realm of chemistry.

• Enduring understandings…

→ All of the natural world around us is composed of three particles – electrons, protons and neutrons – arranged to form the atoms of 118 different chemical elements. In turn, the atoms of these elements bond together to form millions of different compounds.

→ Chemical reactions involve the movement of just a small number of electrons, and yet the changes in the properties of the chemicals are profound.

1. What are some generalisations about systems?

Systems have elements that interact with each other to perform a function.
Systems are made up of sub-systems. Systems may be influenced by other systems.
Systems follow rules. Systems interact.

2. Why can an atom be considered to be a system?

Atoms are made of three sub-atomic particles; electrons, neutrons and protons. These particles can be viewed as sub-systems. The arrangement and movement of the particles follow rules, *e.g.* the protons and neutrons are located in the nucleus, which the electrons orbit in specific energy levels or electron shells.

3. What are some generalisations about models?

Models can be conceptual, mathematical or physical. Models simulate real world processes. Models facilitate testing and prediction. Models simplify real world processes or behaviours. Models involve variables.

4. Why do scientists use a model of the atom to understand the natural world?

Atoms are extremely small, too small to be visualised with even the most advanced microscopes. Based upon experimental evidence, and mathematical models, scientists also think that atoms have a very complex structure. Developing models of the atom help scientists to visualise what atoms might actually look like which in turn helps them to explain phenomena, such as why and how atoms react and bond together.

5. What are some generalisations about change?

Changes occur amidst continuities. Change can be steady, cyclic, random or chaotic.
Change is inevitable. The consequences of change can be good (positive) or bad (negative).
Change is inevitable in all systems. Change can be spontaneous or planned.

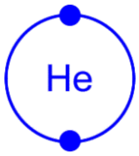
6. Why is change an important concept in chemistry?

Chemical reactions bring about change in a system. Essentially, chemicals react together to produce new products which have different properties compared to the starting materials. The reaction products may have desirable or undesirable properties, *e.g.* the products could be a lifesaving drug, or a harmful greenhouse gas.

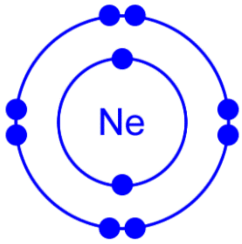
<u>Ionic Bonding – Bonding Between a Metallic Element and a Non-metallic Element</u>

7. In the spaces provided below, draw the electronic configurations of helium, neon and argon.

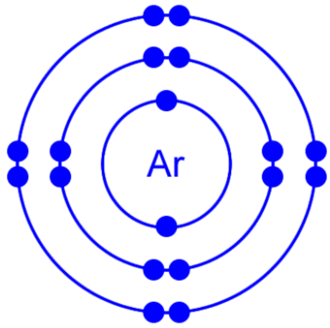
• Helium



• Neon



• Argon

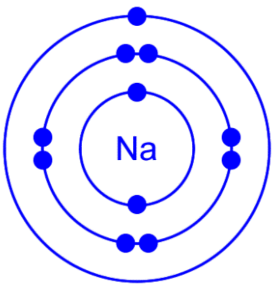


8. What do the electronic configurations of the noble gases all have in common? Why are noble gases unreactive?

Atoms of the noble gases all have complete valence shells. Atoms that have complete valence shells are low in energy and inherently stable, *i.e.* they are very unreactive.

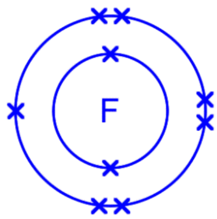
9. In the spaces provided below, draw electronic configurations of sodium (a metallic element) and fluorine (a non-metallic element). Use dots (•) to represent the electrons of sodium and crosses (×) to represent the electrons of fluorine.

• Sodium



Atomic number 11, Group 1, Period 3.

• Fluorine



Atomic number 9, Group 17, Period 2.

10. Predict whether sodium and fluorine are reactive or unreactive elements. Explain your answer.

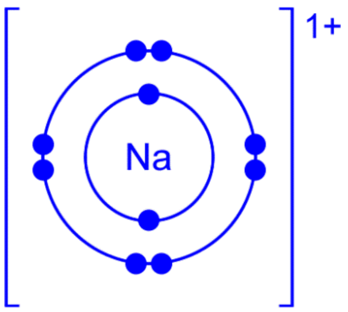
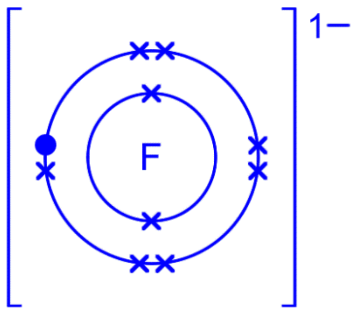
Sodium is a very reactive metallic element and fluorine is a very reactive non-metallic element. Both sodium and fluorine have incomplete valence shells, which makes them inherently unstable and consequently very reactive. Both sodium and fluorine want to react in order to obtain the electronic configurations of noble gases.

11. How can sodium and fluorine cooperate and re-arrange their valence electrons so that both atoms can obtain the electronic configurations of noble gases?

An atom of sodium has a single electron in its valence shell. If this single electron is *lost*, then the next electron shell down will become the new valence shell, which contains a complete *octet* (eight) of electrons. By losing its single valence electron, sodium will have obtained the electronic configuration 2, 8 – the electronic configuration of the noble gas *neon*.

An atom of fluorine has seven electrons in its valence shell. If fluorine *gains* one more electron, then its valence shell will have a complete *octet* (eight) of electrons. By gaining one electron, fluorine will have the electronic configuration 2, 8 – the electronic configuration of the noble gas *neon*.

12. In the spaces provided below, draw the electronic configurations of sodium a fluorine after they have reacted to obtain the electronic configurations of a noble gas. Use dots (•) to represent the electrons of sodium and crosses (×) to represent the electrons of fluorine.

• Sodium Ion	• Fluoride Ion
	

13. The products of the reaction are charged particles called ions. The oppositely charged ions are attracted towards each other by strong electrostatic charges of attraction. How many electrons and protons does the sodium ion contain? What is the charge on a sodium ion? How many electrons and protons does a fluoride ion contain? What is the charge on a fluoride ion?

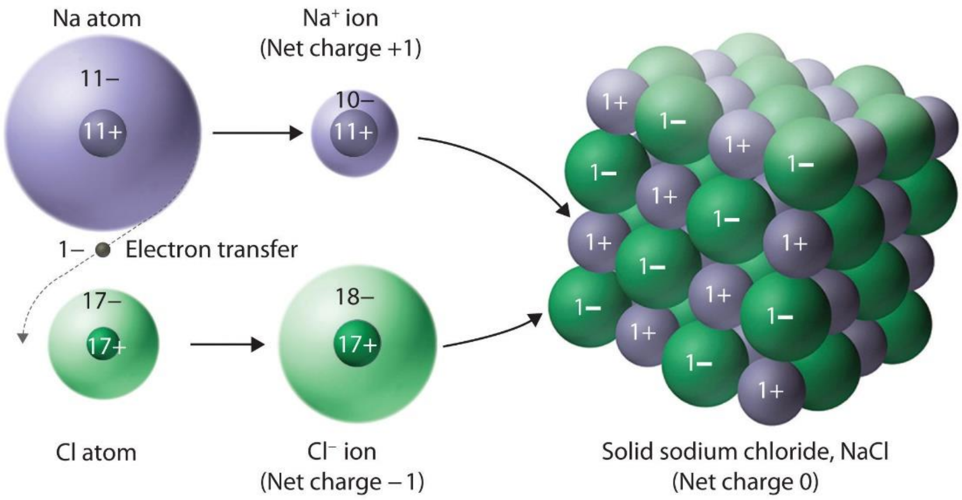
At the start, the neutral sodium atom had 11 positive protons (+11) and 11 negative electrons (–11). At the end, the sodium ion still has 11 protons in its nucleus (+11) but now only has 10 electrons orbiting the nucleus (–10).

The charge on the sodium ion is therefore (+11) + (–10) = +1, written as 1+

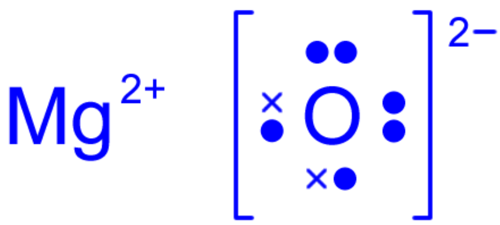
At the start, the neutral fluorine atom had 9 positive protons (+9) and 9 negative electrons (–9). At the end, the fluoride ion still has 9 protons in its nucleus (+9) but now has 10 electrons orbiting the nucleus (–10).

The charge on the fluoride ion is therefore (+9) + (–10) = –1, written as 1–

Note: Ionic bonding occurs in compounds that are composed of a *metal* and a *non-metal*. The metal *transfers* its valence electrons to the non-metal. Both the metal and the non-metal obtain the electronic configurations of the *noble gas* closest to them in the Periodic Table. As a consequence of the electron transfer, the metal forms a *positively* charge ion called a *cation*, while the non-metal forms a *negatively* charged ion called an *anion*. Strong electrostatic forces of attraction between the oppositely charged ions result in the formation of a crystal lattice.



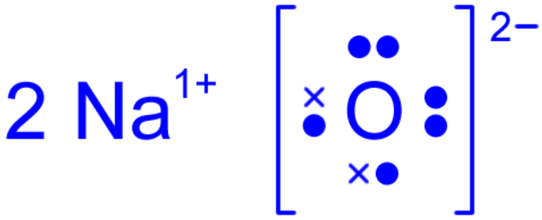
14. Draw a dot-and-cross diagram to clearly show the bonding in magnesium oxide. Include the charge on the magnesium ion, the charge on the oxide ion and a key / legend in you answer.



Formula: MgO

× = electron of magnesium • = electron of oxygen

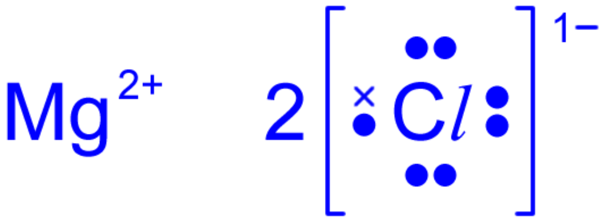
15. Draw a dot-and-cross diagram to clearly show the bonding in sodium oxide. Include the charge on the sodium ion, the charge on the oxide ion and a key / legend in you answer.



Formula: Na_2O

× = electron of sodium • = electron of oxygen

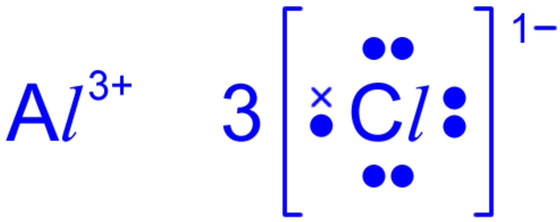
16. Draw a dot-and-cross diagram to clearly show the bonding in magnesium chloride. Include the charge on the magnesium ion, the charge on the chloride ion and a key / legend in you answer.



Formula: $MgCl_2$

× = electron of magnesium • = electron of chlorine

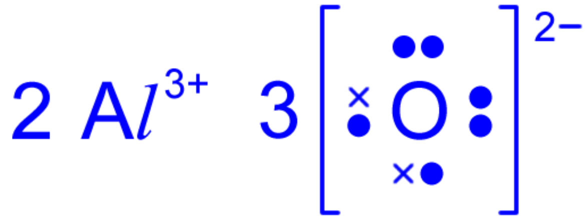
17. Draw a dot-and-cross diagram to clearly show the bonding in aluminium chloride. Include the charge on the aluminium ion, the charge on the chloride ion and a key / legend in you answer.



Formula: $AlCl_3$

× = electron of aluminium • = electron of chlorine

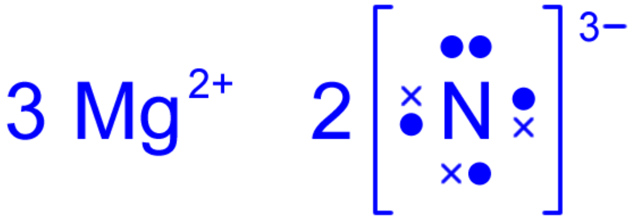
18. Draw a dot-and-cross diagram to clearly show the bonding in aluminium oxide. Include the charge on the aluminium ion, the charge on the oxide ion and a key / legend in you answer.



Formula: Al_2O_3

× = electron of aluminium • = electron of oxygen

19. Draw a dot-and-cross diagram to clearly show the bonding in magnesium nitride. Include the charge on the magnesium ion, the charge on the nitride ion and a key / legend in you answer.

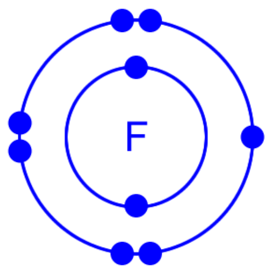
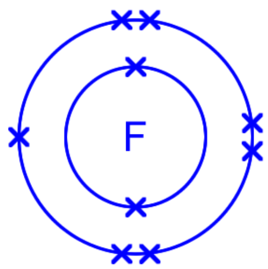


Formula: Mg_3N_2

× = electron of magnesium • = electron of nitrogen

<u>Covalent Bonding – Bonding Between Two or More Non-metallic Elements</u>

20. In the spaces provided below, draw electronic configurations of two fluorine atoms (fluorine is a non-metallic element). Use dots (•) to represent the electrons of one fluorine atom and crosses (×) to represent the electrons of the second fluorine atom.

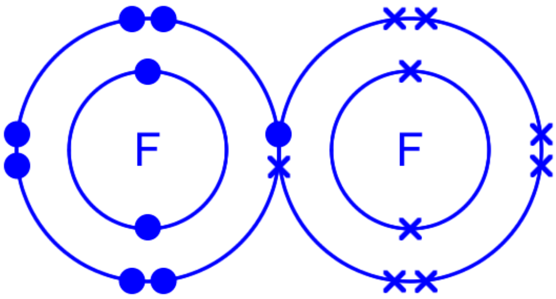
• Fluorine Atom One	• Fluorine Atom Two
	
Atomic number 9, Group 17, Period 2.	Atomic number 9, Group 17, Period 2.

21. Is it possible for both fluorine atoms to obtain the electronic configurations of noble gases by *transferring* electrons form the valence shell of one atom to the other? What problems arise when this happens?

The two atoms of fluorine both have the electronic configuration 2, 7. If the *first* fluorine atom transfers a single valence electron into the valence shell of the *second* fluorine atom, then the *first* fluorine atom will now have the electronic configuration 2, 6 while the *second* fluorine atom will have the electronic configuration 2, 8. Only *one* of the fluorine atoms will have the electronic configuration of a noble gas (2, 8), hence the atoms of two non-metallic elements *cannot* react with each other through electron transfer so that *both* of them obtain the electronic configuration of a noble gas.

22. In the space provided below, draw the two fluorine atoms close together *sharing a pair of electrons*. Use dots (•) to represent the electrons of one fluorine atom and crosses (×) to represent the electrons of the second fluorine atom. By *sharing* (instead of transferring) electrons, both of the fluorine atoms can obtain a noble gas electronic configuration. The pair of electrons that are shared between the two atoms is referred to as a *covalent bond*.

• A Diatomic Molecule of Fluorine – F_2



Note: Covalent bonding occurs between the atoms of *non-metallic elements*. The atoms may be of the same element or of different elements. The atoms come close together, so that their valence shells overlap. The atoms then *share* a pair(s) of electrons in order to obtain the electronic configuration of the noble gas that is closest to them in the Periodic Table. The shared pair of electrons is referred to as a *covalent bond*. It is the mutual electrostatic force of attraction between the positively charged nuclei of the two atoms and the negatively charged shared pair of electrons that holds the atoms together. A small group of non-metallic atoms that are held together by covalent bonds is referred to as a *molecule*. The molecules are *neutral*, *i.e.* they are *not ions* and they *do not carry any overall charge*.

23. Draw a dot-and-cross diagram to clearly show the bonding in hydrogen chloride, HC*l*.

Formula: HC*l*

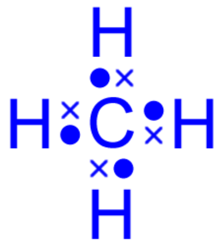
× = electron of hydrogen • = electron of chlorine

24. Draw a dot-and-cross diagram to clearly show the bonding in water, H_2O.

Formula: H_2O

× = electron of hydrogen • = electron of oxygen

25. Draw a dot-and-cross diagram to clearly show the bonding in methane, CH_4.



Formula: CH_4

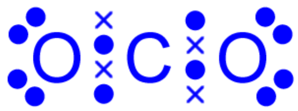
× = electron of hydrogen • = electron of carbon

26. Draw a dot-and-cross diagram to clearly show the bonding in nitrogen, N_2.

Formula: N_2

× = electron of nitrogen (left-hand-side) • = electron of nitrogen (right-hand-side)

27. Draw a dot-and-cross diagram to clearly show the bonding in carbon dioxide, CO_2.



Formula: CO_2

× = electron of carbon   • = electron of oxygen

Summary